

B-hadron Lifetimes from Semileptonics

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Physics Motivation (HQE)

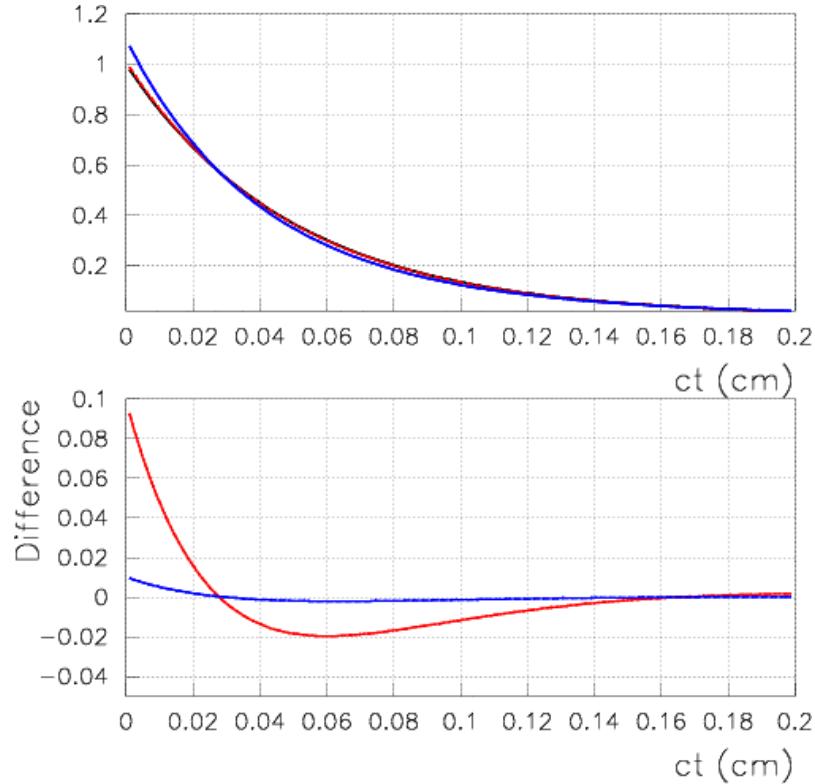
- Many of the B measurements rely on the theoretical calculations for extracting the CKM parameters
 - $\text{Br}(b \rightarrow c\ell\nu) = X \times |V_{cb}|^2$
 - $\Delta m_s / \Delta m_d = Y \times |V_{ts}/V_{td}|^2$
 - X and Y are given by theory and usually have **larger uncertainty** than experiments
- Testing these theoretical models is as important as measuring the CKM parameters
 - Experimental inputs may help to reduce the theoretical uncertainty uncertainty
- Heavy Quark Expansion
 - Expand observable in powers of $(1/m_b)$
 - $\Gamma_b \sim |V_{cb}|^2 m_b^5 [1 + A_v(1/m_b)^n \dots]$
- HQE predict the lifetimes for different B hadron species
 - $\tau(B_c) \ll \tau(\Xi_b^0) \sim \tau(\Lambda_b)$
 $< \tau(B^0) \sim \tau(B_s) < \tau(B^-)$
 $< \tau(\Xi_b^-) < \tau(\Omega_b)$
 - $\tau(B^+)/\tau(B^0) = 1.00 + 0.05 \times (f_B/200 \text{ MeV})^2$
 - $\tau(B_s)/\tau(B^0) = 1.00 \pm 0.01$
 - $\tau(\Lambda_b)/\tau(B^0) \sim 0.9$

(I.I.Bigi)

Physics Motivation ($\Delta\Gamma/\Gamma$)

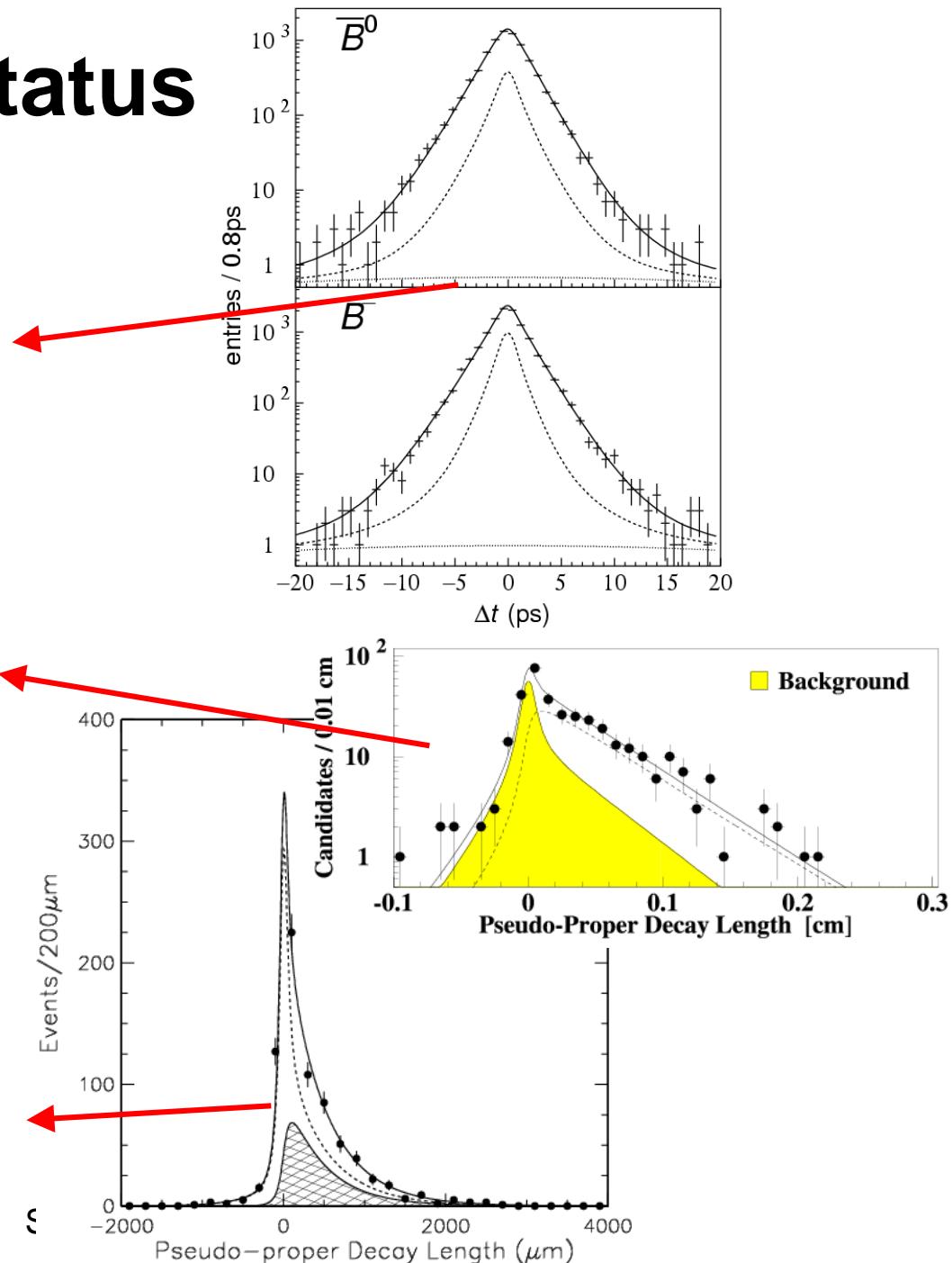
- For B_s $\Delta\Gamma/\Gamma = 5\text{--}15\%$ (SM)
 - $\Delta\Gamma = \Gamma_H - \Gamma_L$ (Heavy, Light)
 - $\text{Br}(B_s \rightarrow D_s^{(*)} D_s^{(*)})$ directly gives $\Delta\Gamma/\Gamma$ (R.Aleksan et al. PLB316,567)
 - Width = (Lifetime) $^{-1}$:
 - Decay time distribution has two lifetime components
 - Measure lifetimes in several different channels with different mass state fractions
- $\Delta\Gamma/\Gamma = A \times \Delta m_s/\Gamma$
 - Large Δm_s : difficult to measure
 - Large $\Delta\Gamma$: easier to measure
 - $\Delta\Gamma/\Gamma$ and B_s mixing are complementary
- $\Delta\Gamma/\Gamma$ is also sensitive to some new physics models

- H:L = 50:50 for semileptonic decays
 - Time distribution for $\Delta\Gamma/\Gamma = 10\%, 30\%$



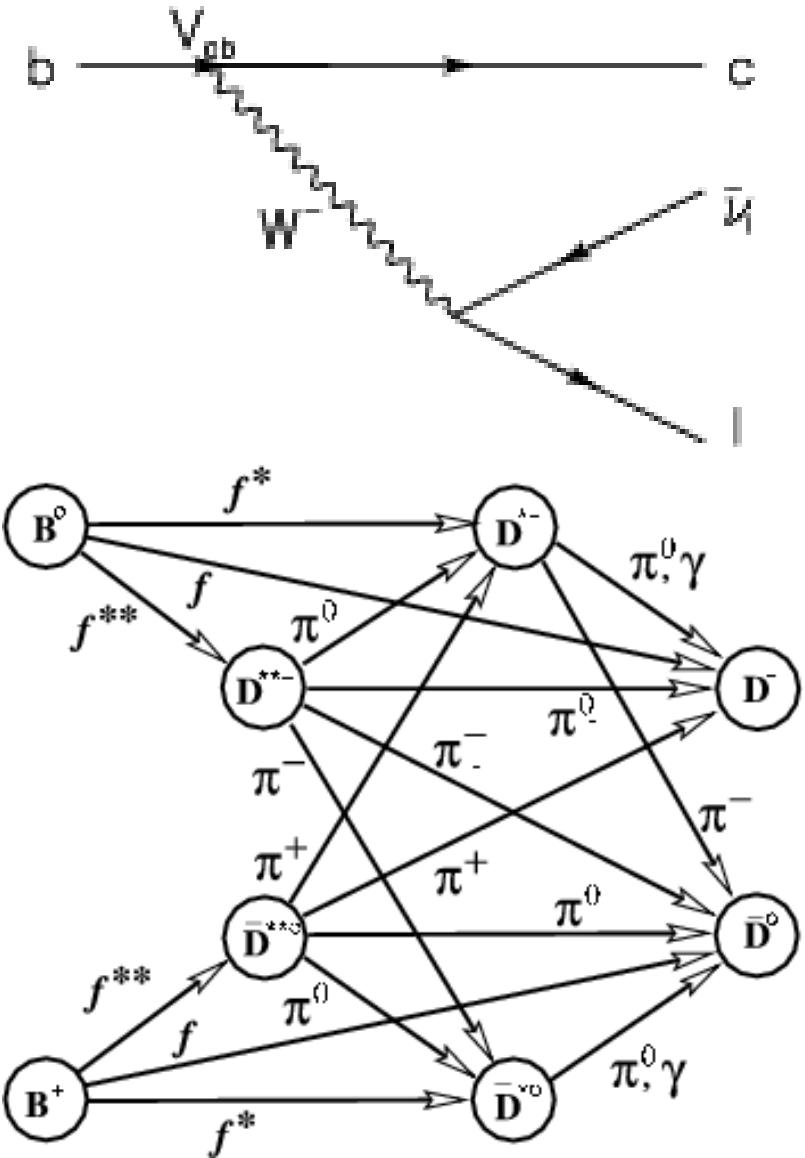
Experimental Status

- B^+ / B^0 lifetime ratio
 - PDG: 1.083 ± 0.017
 - BELLE: $1.091 \pm 0.023 \pm 0.014$
 - CDF-I (Semi): $1.10 \pm 0.06 \pm 0.03$
 - CDF-I (J/ ψ): $1.06 \pm 0.07 \pm 0.02$
- B_s average lifetime
 - PDG: 1.461 ± 0.057 ps
 - CDF-I (semi): $1.36 \pm 0.09 \pm 0.06$ ps
 - CDF-I (J/ ψ): $1.34 \pm 0.23 \pm 0.05$ ps
- $\Delta\Gamma/\Gamma B_s$
 - PDG: < 0.31 (95% CL)
 - CDF-I (semi): < 0.83 (95% CL)
- Λ_b average lifetime
 - PDG: 1.229 ± 0.080 ps
 - CDF-I (Semi): $1.32 \pm 0.15 \pm 0.07$ ps



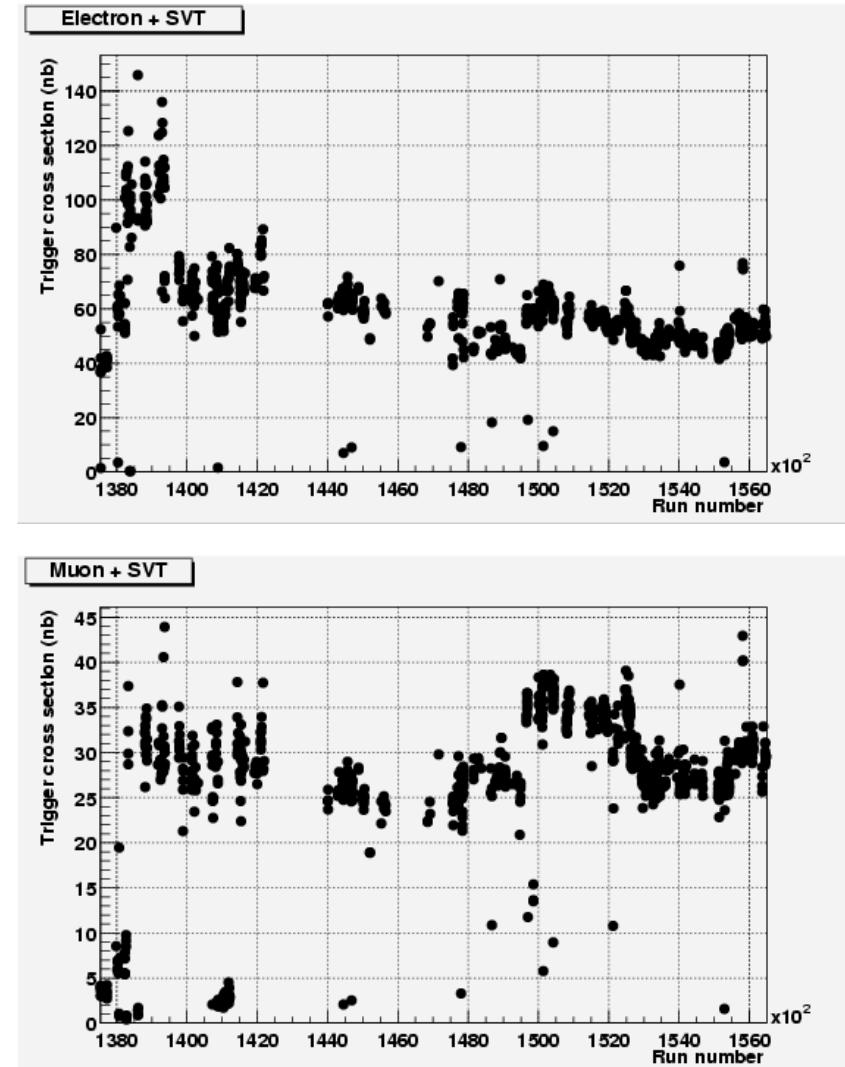
Semileptonic Decay

- Semileptonic Decays
 - $b \rightarrow c \bar{l} \nu$: Br ~ 10% good!
- Typical decay mode
 - $B^0 \rightarrow l \nu + D^{(*, **)+}$
 - $B^+ \rightarrow l \nu + D^{(*, **)0}$
 - $B_s \rightarrow l \nu + D_s^{(*, **)}$
 - $\Lambda_b \rightarrow l \nu + \Lambda_c$ (+higher states)
- Semileptonic B decays are complicated
 - 8 different $B \rightarrow l D^0 X$ chains
- Momentum of B isn't fully reconstructed
 - ν, π^0, γ , etc, are missing



Lepton + SVT Trigger

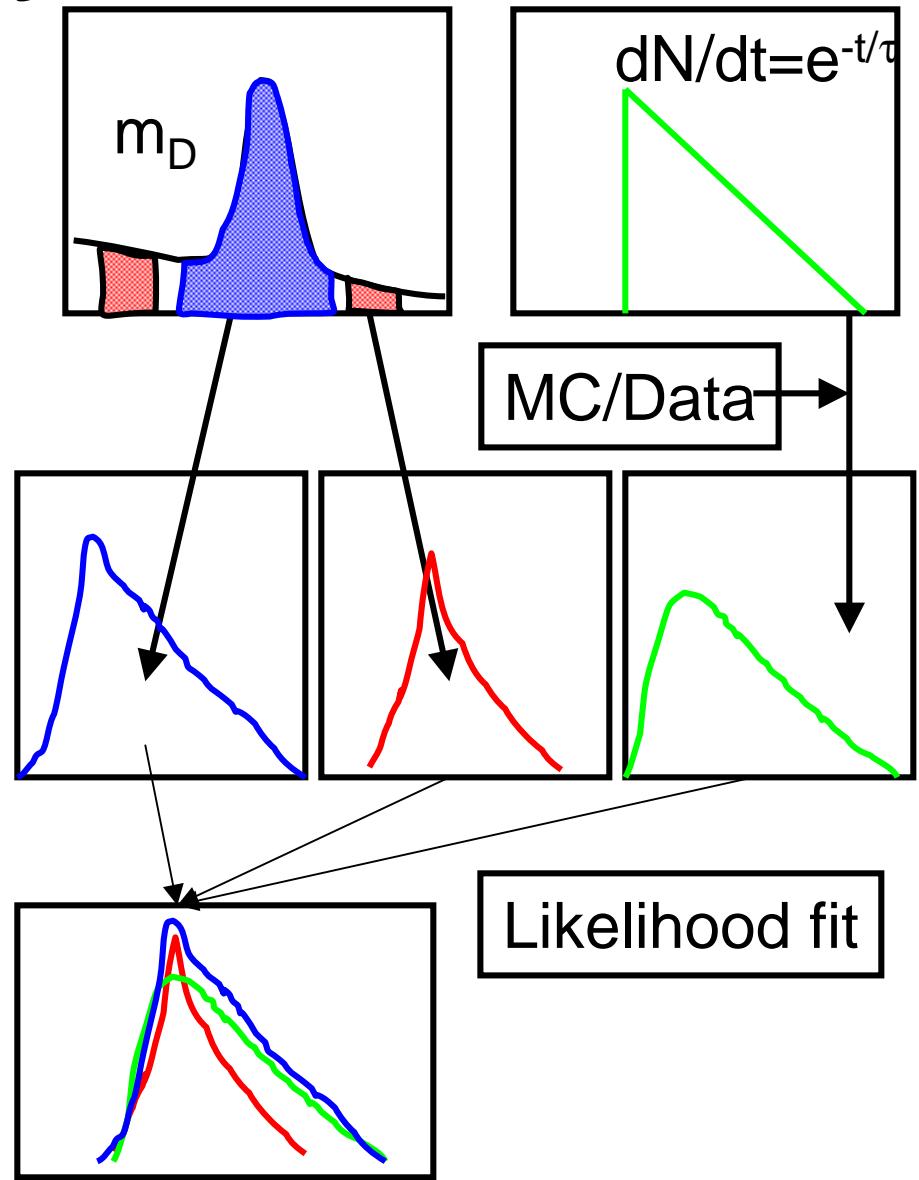
- Replacement of the Run I 8 GeV single lepton trigger
 - 4 GeV lepton + 2 GeV track (=charm decay daughter) with impact parameter (SVT)
 - X~4 gain in acceptance by the lower p_T threshold
- Level 1
 - Electron: 4 GeV central: 25 μb
 - Muon: 4 GeV CMUP: 2 μb
- Level 2
 - 1 SVT with $120 \mu m \leq |d_0| \leq 1 mm$
 - Electron: 350 nb
 - $2 < \Delta\phi(e-SVT) < 90$ degree
 - Muon: 200 nb: no $\Delta\phi$ cut
- Level 3
 - Offline lepton object
 - $M(l-SVT) < 5 GeV$



L3 Lepton + SVT trigger rate

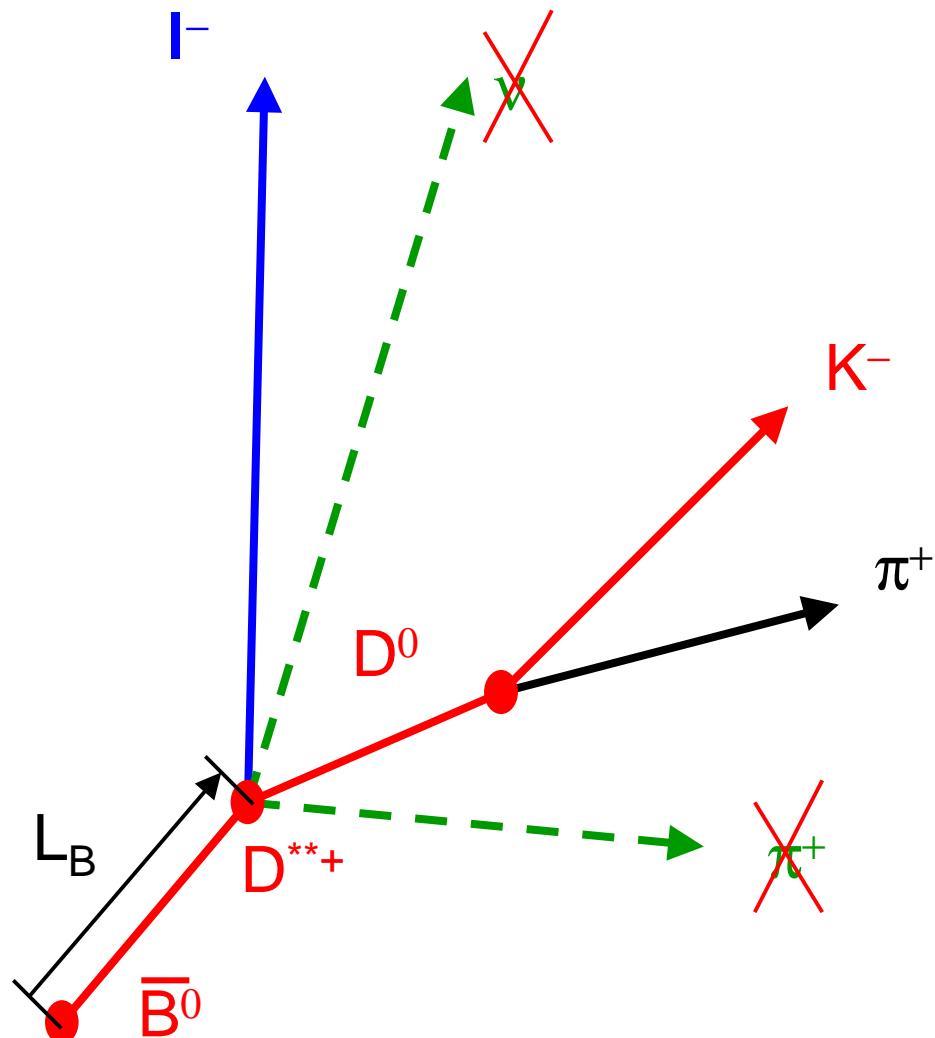
Lifetime Analysis Flow Chart

- (1) Reconstruct signal
- (2) Calculate decay time
- (3) Estimate background
 - Use D mass sideband
- (4) Estimate the bias to the decay time distribution
 - K factor
 - SVT impact parameter cut
 - Resolution smearing
- (5) Extract the lifetime
 - Likelihood fit



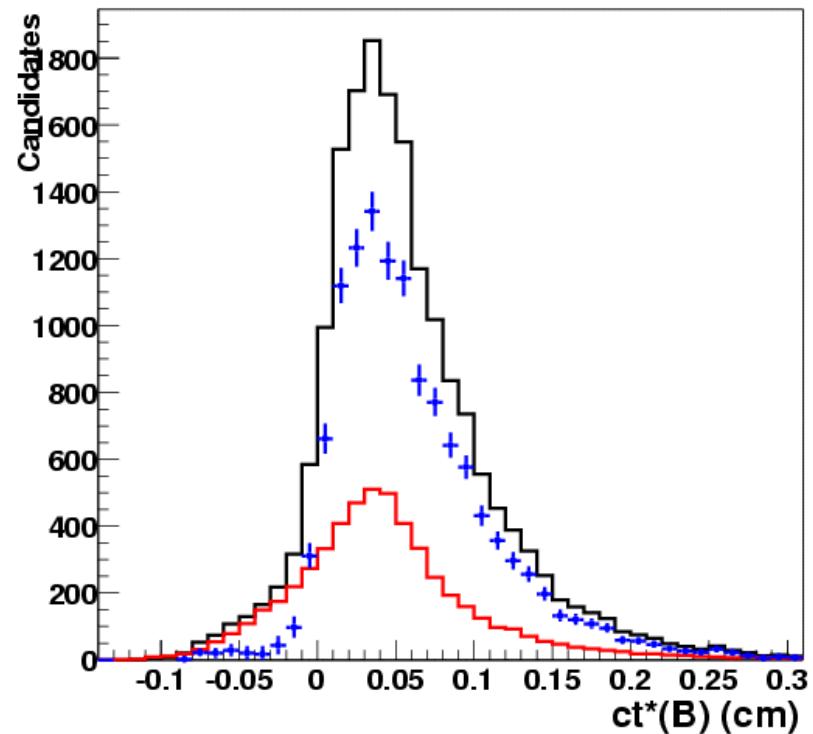
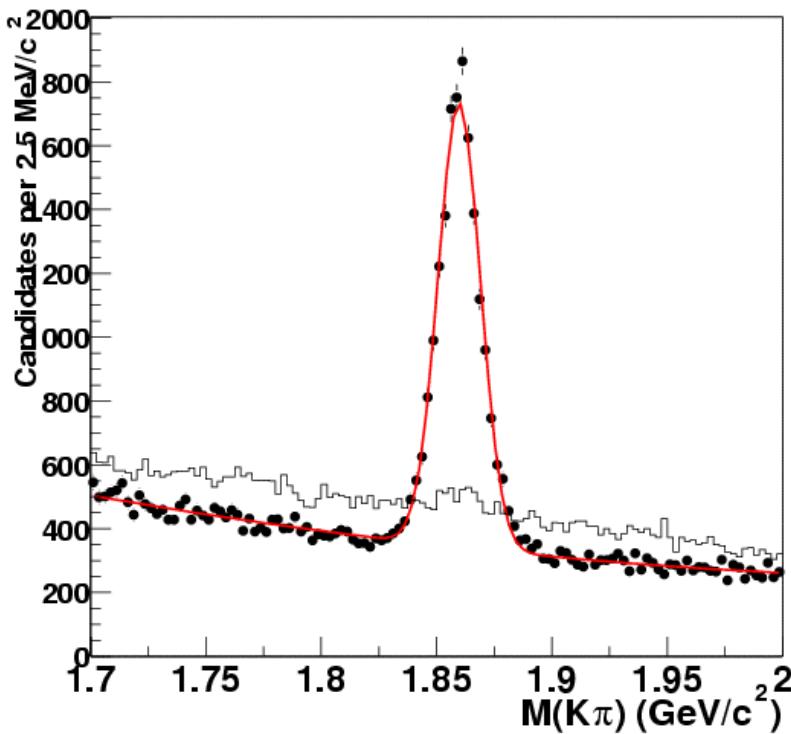
Semileptonic B reconstruction

- $\bar{B}^0 \rightarrow l^- \nu D^{**+}$
 - $D^{**+} \rightarrow D^0 \pi^+$, $D^0 \rightarrow K^- \pi^+$
- l and K have charge correlation
 - $Q_l = Q_K$: Right sign
 - $Q_l \neq Q_K$: Wrong sign
- ν and π^+ are missing
 - Reconstructed momentum $P_{ID} = P(l + D^0)$
- Decay length of B (L_B)
 - Intersection of the μ and $D^0 (=K+\pi)$ tracks
- Pseudo decay time ct^*
 - $ct^* = L_B m_B / p_{ID}$



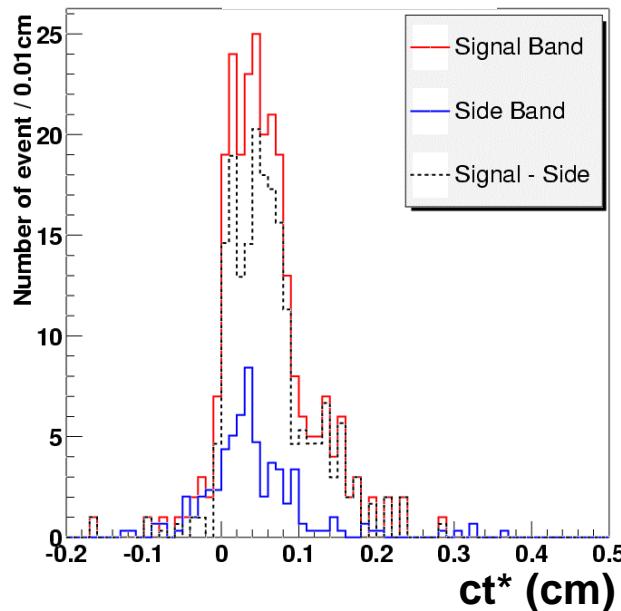
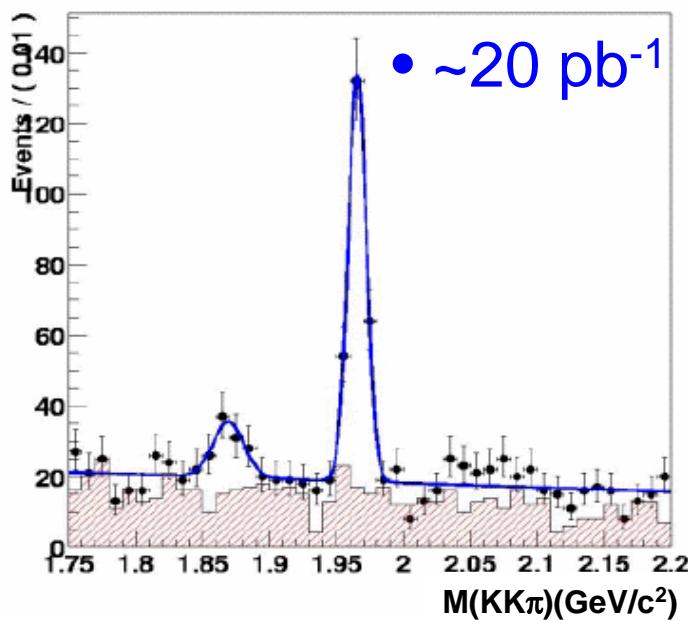
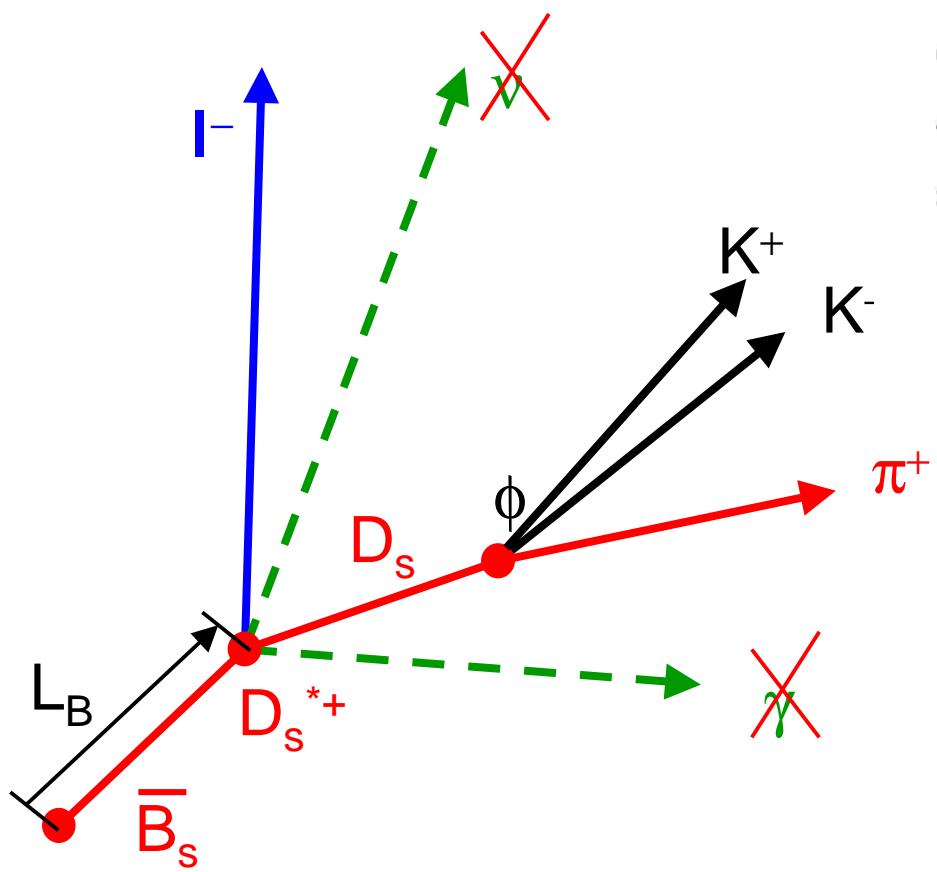
$\bar{B}^0/B^- \rightarrow l\nu D^0 X$ signal (Satoru)

- 13K signal events
 - Full lepton+SVT data(60pb^{-1})
 - Points: right sign
 - Histograms: wrong sign
- Pseudo decay time distribution
 - Black: signal region
 - Red: side band
 - Blue: Sig - SB



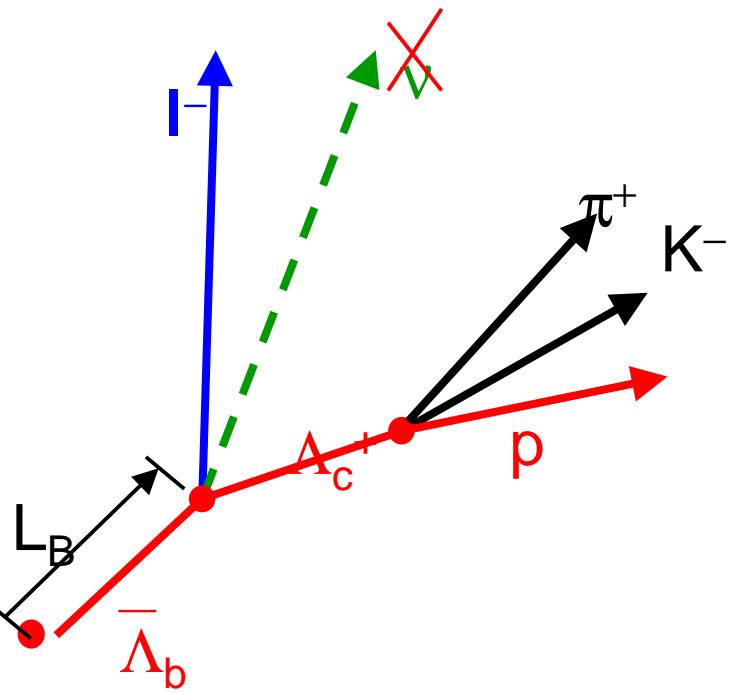
$B_s \rightarrow l\nu D_s X$ signal (Jaison,Satoru,Sinead)

- $B_s \rightarrow l\nu D_s^{*+}$
- $D_s^{*+} \rightarrow D_s^+ \gamma$,
- $D_s^+ \rightarrow \phi \pi^+ \rightarrow K^+ K^- \pi^+$

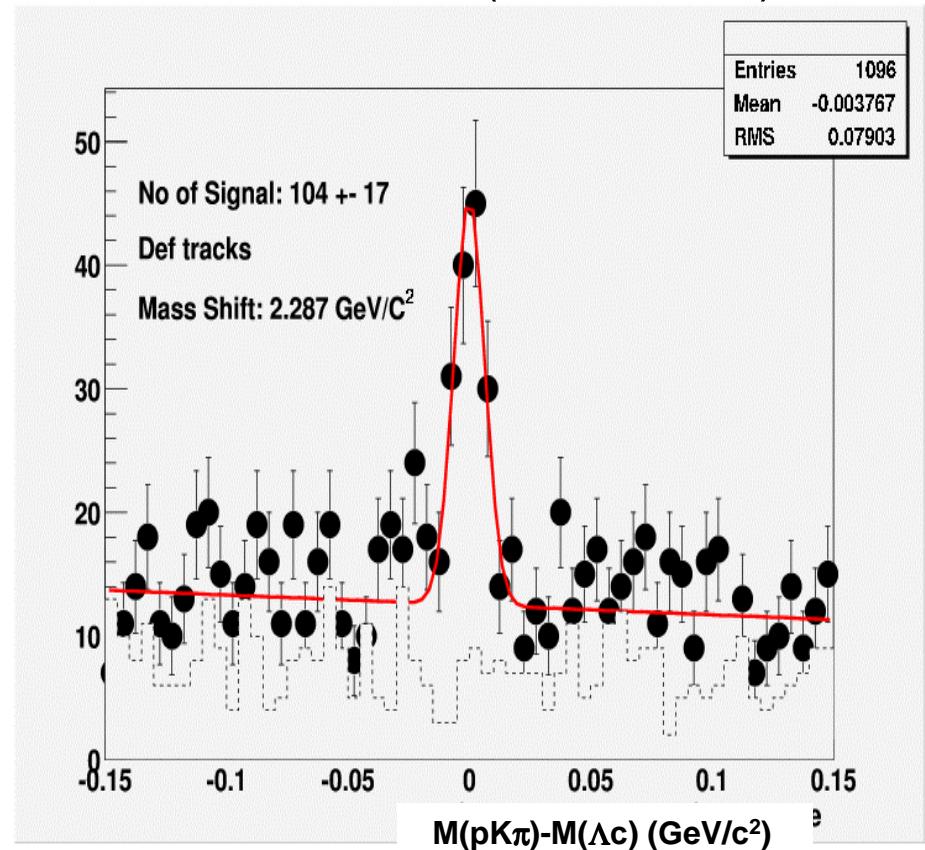


$\Lambda_b \rightarrow l\nu \Lambda_c^+ \text{ signal (Kai, Tatjana)}$

- $\Lambda_b \rightarrow l\nu \Lambda_c^+ (X)$
 - $\Lambda_c^+ \rightarrow p K^- \pi^+$



- From early data: $\sim 20 \text{ pb}^{-1}$
 - Use TOF for proton ID
 - Excellent S/B (Run I $\sim 1/3$)



Lifetime (K factor)

- Real decay time

- $ct = L_B m_B / p_B$

- B isn't fully reconstructed

- We can't measure p_B but p_{ID}

- $ct = L_B m_B / p_B$

- $= L_B m_B / p_{ID} \cdot K$

- Estimate $K = p_{ID}/p_B$ from MC

- K factor depends on

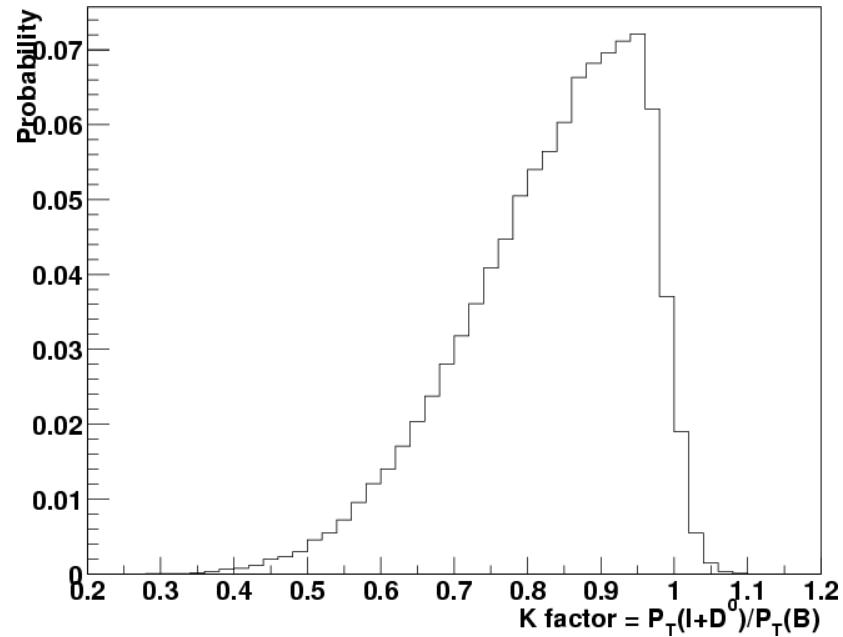
- Generated p_{TB} distribution

- Sample composition

- Decay model

- Trigger/offline cuts

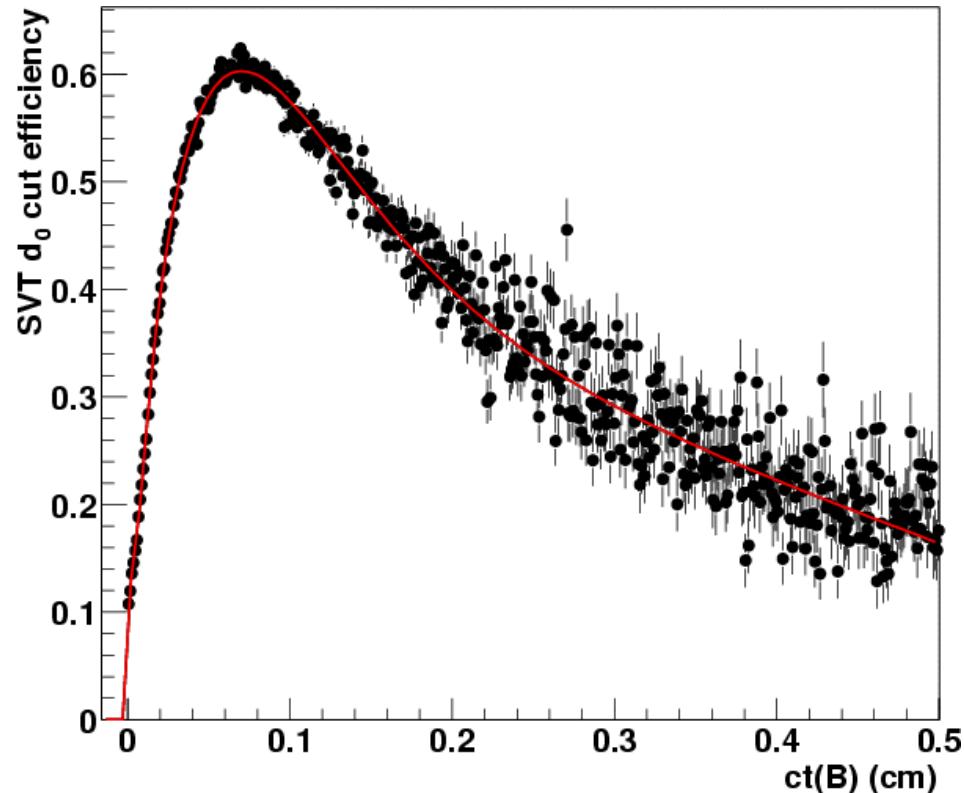
- Brems energy loss of electron (large material)



- K factor resolution $\sim 15\%$
- Can be improved by
 - Use correlation with $M(ID)$
 - Use 3D vertexing information
- It is important for measuring Δm_s in the semileptonic decay

Lifetime (SVT bias)

- Decay time distribution
 - $dN/dt = e^{(-t/\tau)}$
- SVT impact parameter cut
 - $120 \mu\text{m} \leq |d_0| \leq 1 \text{ mm}$
 - Changes the distribution
 - $dN/dt = e^{(-t/\tau)} \times \text{eff}(t)$
 - Estimate this efficiency curve from MC
- SVT bias depends on
 - Decay kinematics (p_T , $\Delta\phi$)
 - SVT tracking efficiency
 - SVT d_0 resolution
 - SVT configuration (map, fit constant)



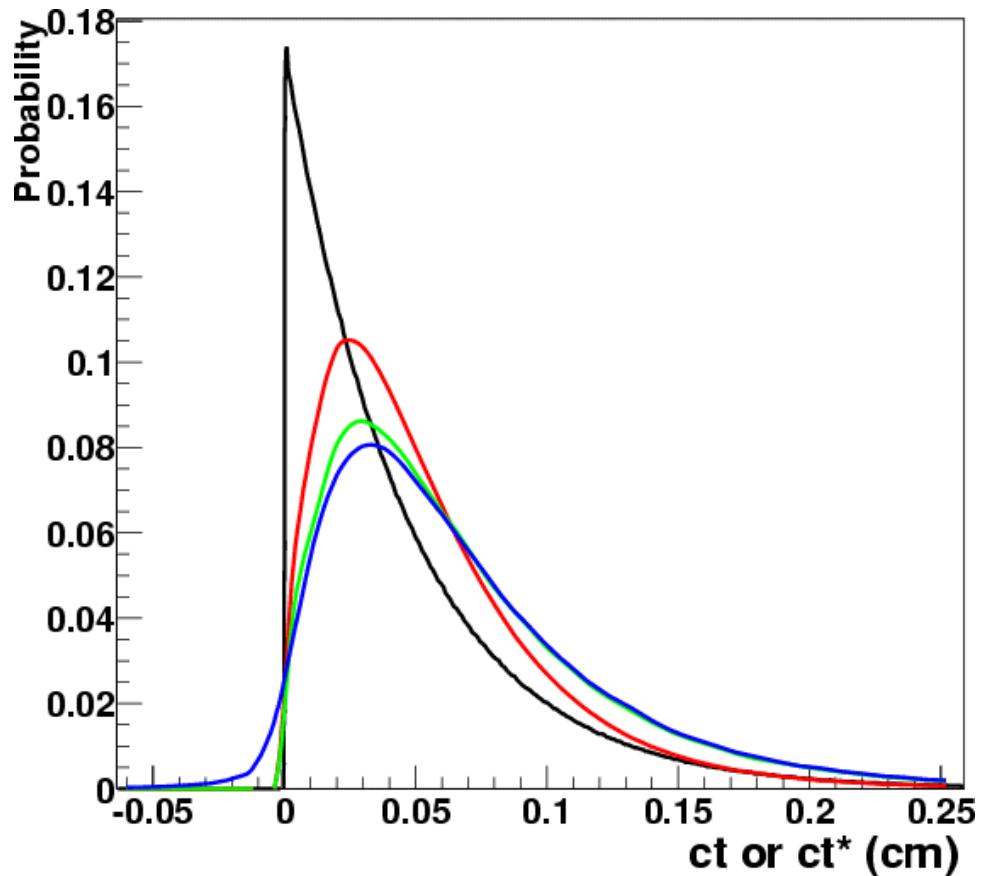
Lifetime (Likelihood Fit)

- Signal Likelihood

- $L(t', \sigma t'; \tau) = e^{(-t/\tau)}$
- $\times \text{eff}(t)$
- $\otimes F(K)$
- $\otimes R(t', t; \sigma_{t'})$

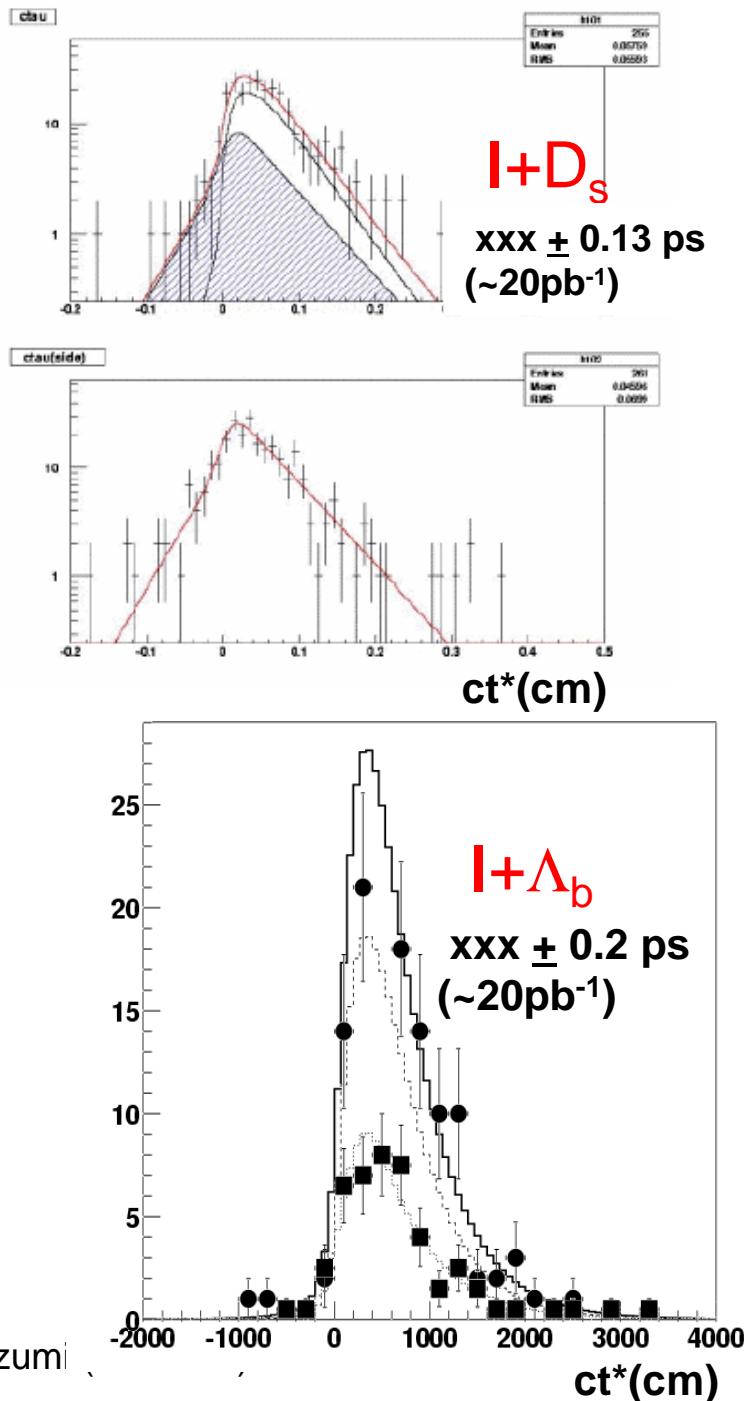
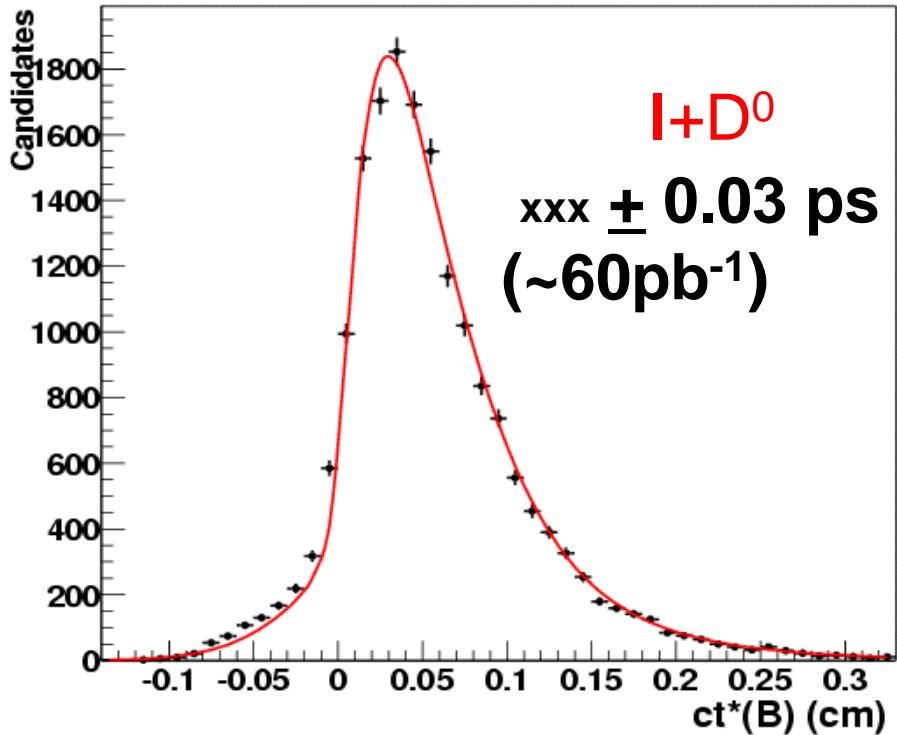
- Likelihood distribution

- Physics (exponential)
- Apply SVT efficiency
- Apply K factor
- Apply resolution function



Fitting Results

- Analyses are still going on
- Lifetime fit results aren't yet ready to be shown ...



Summary / Plan

- We are measuring lifetime in the semileptonic decays in the Lepton + SVT sample.
- We have $\sim 13K$ of $I+D^0$, and expect 500 $I+D_s$, and ~ 300 $I+\Lambda_c$, in $\sim 60 \text{ pb}^{-1}$ of the data
 - $\times 2\text{--}3$ higher statistics than Run I 8 GeV lepton dataset (100 pb^{-1})
 - $\times 10$ higher than the exclusive decays in Run II J/ψ dataset (60 pb^{-1})
- There are two important issues for measuring lifetime
 - Correct for the missing momentum (K factor) – Done in Run I CDF
 - Correct for the bias from the SVT impact parameter cut.
 - Totally new in Run II CDF
 - Challenging, but it must be done for future analyses (Bs mixing,etc)
- Plan: Get blessed the preliminary B^+/B^0 , B_s , Λ_b lifetime measurements for Moriond ~ APS